Status and Trends Database Maintenance Project
Final Report

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Galveston Bay Estuary Program

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1. Introduction

1.1 Bay History/Nature of the Bay

Galveston Bay has a history of human use going back thousands of years. It provided food and implements to the indigenous peoples long before Europeans visited its shores. Since 1845 it has developed a pattern of resource use shared with other states in the United States. Thus the Bay has been a source of materials for industrial, agricultural and urban development as well as a recipient of waste from those developments.

Galveston Bay is a sub-tropical estuary fed by two major rivers and surrounded by low-lying wetlands, a barrier island and peninsula. The water is generally quite shallow and in some places made shallower by extensive oyster reefs. The Bay has increased in volume over the last 50 years due to subsidence and sea level rise. The bottom sediment is mostly fine-grained material, mud, silt and sand, mixed in some places with shell. The tidal amplitude is small compared to estuaries on the East and West Coasts, averaging about 0.3 meters. Circulation is primarily driven by tides and wind.

Productivity is high. Galveston Bay has supported large fisheries for oysters, shrimp and fish for more than 50 years. The energy for animal production comes from two sources: 1) the algae and seagrasses that grow in the open bay and are eaten as living tissue by herbivores; and 2) the detritus coming primarily from dead plants in the salt marshes and riverine wetlands around the Bay. In addition to aquatic animals, large numbers of water birds depend on the productivity of Galveston Bay, both as residents and as over-wintering populations.

The physical and biological nature of Galveston Bay is described in detail in State of the Bay 2nd edition. In this Status and Trends report, we are providing current analyses of monitoring data to add detail to the picture of Galveston Bay that has already emerged from the work of many experts.

1.2 User Impacts

The Bay has many user groups and each group impacts the physical and biological systems of the Bay. Fishermen use the Bay for commercial and recreational fishing, thus impacting the flow of energy through the ecosystem, the mortality rates of many species, the topography of the bottom and the turbidity of the water. Industry uses the water of the Bay and its tributaries for cooling purposes; impacting water temperature, and mortality rates of species through entrainment and impingement. Industry also uses bay and tributary waters as an end location for wastewater effluent, thus impacting the concentration of pollutants in the Bay and tributaries. Barge and vessel transportation impact the Bay by dredging channels, building docks, creating water turbulence, spilling fuels and other contaminants, and dispersing non-indigenous species. Recreational boaters have similar, but smaller impacts. Residents use the Bay for discharge of treated sewage and non-point source run-off from their property and nearby roadways, thus impacting the concentration of pollutants.

1.3 Relationship to the Galveston Bay Plan

The Galveston Bay Estuary Program (GBEP) administers the Galveston Bay Plan, a consensus-based program to manage the Bay with fewer negative impacts and to restore components of the Bay system impacted by poor management in the past. The Plan has many goals that relate to the health of the Bay. Our ability to assess progress toward those goals is constrained by the information we can extract by monitoring selected parameters.

The data employed in this report are the result of public monitoring programs by government agencies. These monitoring programs were initiated following the passage of environmental protection laws in the late 1960's and early 1970's. Water and sediment quality monitoring programs are the direct result of clean water legislation nationally and in Texas. Monitoring of living resources is tied to the concern for wildlife embedded in environmental and fish and game legislation.

Some of the monitoring programs have been consistently maintained for more than 20 years. Others have been intermittent and have spatial and temporal gaps in the data sets. Additional data sets have been implemented more recently and have limited temporal ranges. Gaps and short temporal ranges make the determination of trends difficult or impossible.

Management of the Bay and implementation of the Plan will be aided by careful elimination of potential gaps in data collection and by uninterrupted implementation of some recent and intermittent monitoring programs, e.g. Texas General Land Office (GLO) oil spill reporting, wetlands mitigation monitoring, and Texas Department of Health (TDH) health consultations.

The Status and Trends project is primarily focused on data collected by agencies under quality assurance plans that are or could be approved by the EPA. Trends in parameters or groups of parameters as well as status of indicator parameters will permit assessment of the health of the Bay and its associated resources.

The Status and Trends Report can inform us about the changes in the Bay that have been documented in the available data sets. It cannot elucidate changes that have occurred over a longer temporal period or in areas not adequately sampled. We have for most data sets consolidated data by sub-bay to maximize number of observations while maintaining a geographic perspective. Multivariate analyses focus on Trinity, Upper and Lower Galveston Bay and West Bay because, compared to the tributaries and East Bay, these have large sample sizes for the widest variety of parameters.

1.4 Related Natural Events

Human use is not the only causal factor impacting Galveston Bay. There are natural processes that alter the Bay. Three natural phenomena that are of major concern to Galveston Bay and surrounding land are hurricanes, flooding and relative sea level rise associated with land subsidence.

Only one major hurricane (Alicia in 1983) has struck the Galveston Bay area during the period of data collection used in this report. It is difficult to detect many long-term changes from hurricane Alicia. However, it did change the size of several islands in the Bay and the placement of sediment around San Luis Pass.

Flooding is part of the natural hydrological regime in southeast Texas, but not all floods are equal. Some floods contribute large quantities of sediment to the Bay and dramatically change the salinity. This has been less common following the construction of dams on the Trinity and San Jacinto Rivers.

The combination of sinking land and rising sea levels can significantly alter a bay over time, one local example being Galveston Island. Galveston Island is only about 5,000 years old. Prior to that time changes in sea level submerged the island across the mouth of the Bay. In the case of modern Galveston Bay, relative sea level rise occurs at a rate greater than sediment can accumulate. As a result, Gulf and estuarine waters submerge beachfront and marsh land in the area. Sea level is expected to continue rising and reaching higher rates in the future. Submergence of marshes would, in most undeveloped areas, result in marsh expansion shoreward, but regional topography and conflicting land use makes growth of equivalent marsh areas around Galveston Bay unlikely. This report does not examine hurricanes, flooding or relative sea-level rise as causative factors for any of the trends of monitoring parameters.

2. Data Acquisition and Database Construction

2.1 Data Types and Contributing Agencies

A number of state and federal agencies collect environmental data for the Galveston Bay system through their regular monitoring programs. These data relate to water and sediment quality, freshwater inflows, living resources, oil spills and seafood safety. The Status and Trends project acquired relevant data sets for the Galveston Bay system for the period of record over which the agencies collected the data. Descriptions of the environmental data sets and the agencies that collect and maintain them follow.

The Texas Commission on Environmental Quality (TCEQ) (formerly the Texas Natural Resource Conservation Commission or TNRCC) maintains the Surface Water Quality Monitoring (SWQM) database. This collection of data for the Galveston Bay Estuary Program's (GBEP) study area contains 470,172 individual measurements and dates back to 1969. It includes parameters relating to water and sediment quality, which the TCEQ regularly samples as a function of its regulatory duties. Data are also collected by the TCEQ through the Clean Rivers Program. Locally, the Clean Rivers Program is administered by the Houston-Galveston Area Council (H-GAC). It coordinates the local monitoring efforts of six government entities including the U.S. Geological Survey, the TCEQ local field office, the Galveston County Health District, Harris County Pollution Control, the City of Houston, and the San Jacinto River Authority.

The Texas Parks and Wildlife Department (TPWD) maintains the database on fisheries resources for Galveston Bay. This database is separate from the commercial and recreational fisheries database held by the agency. The fisheries resource database contains 607,039 records sampled in the GBEP study area and dates back to 1975. It includes information on a host of aquatic plants and animals sampled by the agency using a wide variety of sampling techniques. This database was used to analyze species abundances in East Bay, Upper and Lower Galveston Bay, Trinity Bay and West Bay. TPWD also collects hydrological data in association with its fisheries independent monitoring program. TPWD hydrological parameters including dissolved oxygen, water temperature, and salinity were analyzed by the Status and Trends Project.

Data on colonial nesting bird populations for the Texas coast are collected by volunteers on an annual basis and are maintained by the U.S. Fish and Wildlife Service (USFWS). The database contains 679 records in the GBEP study area and reports number of nesting pairs for 29 species of birds sighted in Galveston Bay during the years 1973-2001.

Data on oil spills in Galveston Bay are collected and held by the Texas General Land Office (GLO). This database contains 1,646 records and describes spills of 12 types of petroleum products. The oil spills database describes spills that occurred in the Galveston Bay estuary during the time period of January 1998 - April 2002.

The Texas Water Development Board (TWDB) maintains data on freshwater inflows to Galveston Bay. The Status and Trends project acquired this agency's data relating to freshwater inflows into the Neches-Trinity Coastal Basin, the San Jacinto-Brazos Coastal

Basin, and the San Jacinto and Trinity River Basins for the years 1977-1999. Surface inflows are calculated by the TWDB as a function of gaged flows, modeled flows, diversions and return flows.

Seafood safety data was collected by the Texas Department of Health (TDH) through a series of Health Consultations conducted throughout Galveston Bay during the period 1998-2000. The TDH Health Consultations looked at concentrations of pollutants in finfish and blue crab tissue to determine whether human exposure to pollutants occurred and whether or not a threat to public health was present. The Health Consultation data reports on concentrations of metals, pesticides, polychlorinated biphenyls (PCBs), semivolatile compounds, volatile compounds, and dioxins and furans measured in the tissues of finfish and blue crab.

2.2 Database Construction

Databases were acquired from the source agencies via download from the Internet or via files sent to the Status and Trends project by the source agency. Data came from the agencies in ASCI or MS Excel formats. Data were then converted into a relational database using MS Access.

Construction of the water and sediment quality database differed from all others in that the TCEQ maintains the data in three separate files. The Event file contained information collected by field technicians at the time samples were collected. The Result file contained information generated through laboratory analysis. The Stations file contained descriptive information on TCEQ sampling locations. The Event, Result and Station files were merged into one table containing all information. Data collected and held separately by the H-GAC Clean Rivers Program were merged in a similar fashion and combined with the TCEQ data set. Queries were created within the database for each parameter analyzed based on sampling location.

Data on fisheries resources supplied by the TPWD went through its own set of preparatory steps prior to trend analyses. The TPWD uses a variety of gear to sample and monitor populations of aquatic organisms in Galveston Bay. Only those samples collected with gill net, shrimp trawl, bag seine or oyster dredge were incorporated into the Status and Trends analyses. Data were converted from number captured to catch per unit effort (CPUE). For gill net, shrimp trawl and oyster dredge, CPUE is calculated as total number captured per total time sampled. CPUE for bag seine is calculated as total number captured per total area sampled. Queries were created within the database for each species analyzed based on sampling gear and sample location.

Other databases acquired by the Project were in a simple format and did not go through the preparatory steps described above. Duplicate data entries in each data set were identified and removed. Outlying or negative values were validated or deleted from the analyses.

2.3 Metadata

Metadata are a valuable part of any data set, providing information on how the data were collected and how they should be treated during analysis. The metadata for each database were acquired from the source agencies when available, e.g. TCEQ and TPWD operations manuals and other guidance documents (TCEQ, 1999; TPWD, 2000). Unfortunately, some agencies did not have metadata documentation to accompany their data sets. In these cases the Status and Trends project relied upon the professional advice of agency representatives most familiar with the data sets.

The Status and Trends project created metadata describing the project's data processing methodology. This metadata does not describe source agency methods for obtaining, processing and quality assuring the original agency data. For this information, one should refer to the source agency operations manuals (TCEQ, 1999; TPWD, 2000).

Metadata for geographic and numeric analyses created through the Status and Trends project are included in Appendix G.

3. Data Processing

3.1 Spatial Formatting: GBEP Segmentation Scheme

The GBEP segmentation scheme, seen in Figure 3.1.1, was converted into a GIS layer and overlaid onto the sampling locations of the TCEQ, TPWD, Clean Rivers Program, and TDH (see Appendix A). The GBEP segmentation scheme was originally created by Ward and Armstrong (1992). It assigned a letter and number designation to specific areas within Galveston Bay.

The Status and Trends project consolidated GBEP segments based on their letter designation (see Table 3.1.1). Doing this allowed us to group data by sub-bay and tributary. This maximized the number of observations for analyses while maintaining a geographic perspective. Data obtained from agency sampling stations located outside the GBEP study area were eliminated and not included in the Status and Trends analyses.

Figure 3.1.1. GBEP Segmentation Scheme. Modified from Ward and Armstrong (1992).

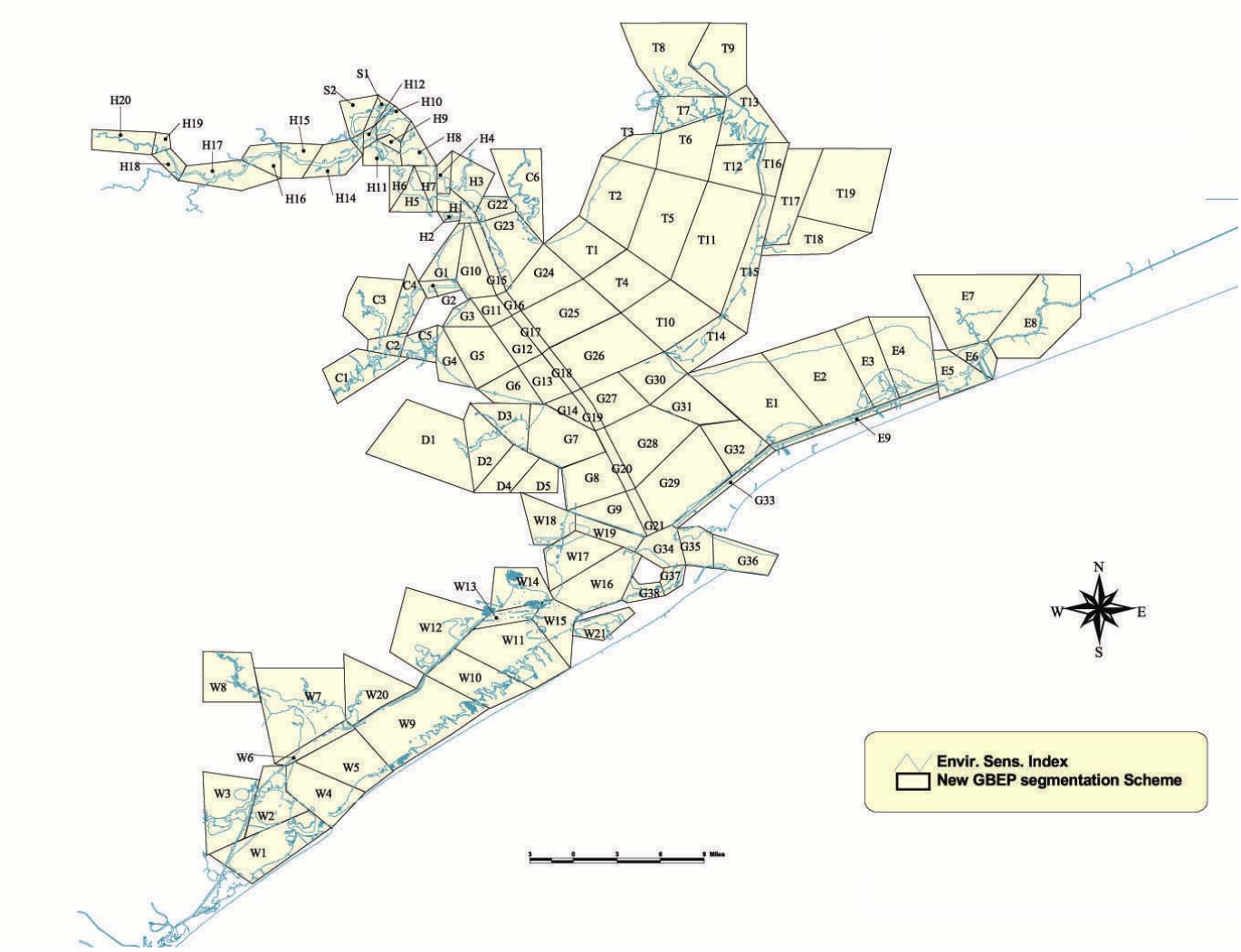

Table 3.1.1. Consolidation of GBEP Segments into Major Sub-bays and Tributaries of Galveston Bay.

GBEP Segment ID	Sub-Bay or Tributary Name
C	Clear Creek and Clear Lake
C6	Cedar Bayou
D	Dickinson Bayou and Dickinson Bay
E	East Bay
G	Upper and Lower Galveston Bay
H	Houston Ship Channel
S	San Jacinto River
T	Trinity Bay
W	West Bay
W8	Chocolate Bayou
W18	Texas City Ship Channel

3.2 Temporal Formatting

Data provided to the Status and Trends project often had sampling dates reported as a complex date, e.g. day/month/year/time. For the purposes of annual, monthly and seasonal trend analyses, the complex dates were separated into day, month, year and time fields within the databases.

4. Data Analysis

4.1 Data Structure

4.1.1 Spatial Structure

An ideal data set for analysis of the spatial distribution of environmental parameters would consist of measurements from large numbers of randomly distributed sampling sites, a set of evenly distributed sites arranged in a grid, or a set of sample sites selected to represent chosen conditions with replication.

Of the data sets analyzed by the Status and Trends project, the fisheries resource data set from the TPWD is the only one that uses randomly selected sampling sites. Random selection provides advantageous statistical properties for analyses of single and multiple species data. The spatial coverage of the Bay is sufficient with the four collection methods analyzed by the Status and Trends Project (shrimp trawl, bag seine, gill net and oyster dredge) to assume statistically valid coverage of the area.

The water and sediment quality data set from TCEQ is obtained from collections at a set of fixed sampling sites chosen for relevance to both monitoring and regulatory needs. Sample sites for water and sediment quality are concentrated in areas that have discharges, principally tributaries and dredged channels. Some sample sites exist in the open bay waters, however the density of sampling sites is considerably lower in the Bay than in tributaries and channels.

Spatial issues do occur with other data sets as well. The oil spill data set is dependent upon non-randomly, non-evenly distributed observers who must report a spill for it to be recorded. A similar problem exists with the data from the survey of nesting birds. Data collection from a colony is dependent upon sighting by a set of non-randomly and non-evenly distributed observers. It is not clear in either case that the spatial coverage of the Bay and associated land areas is adequate to claim complete coverage. Given that the sampling has no obvious bias or gaps, the results will be reported as representative of the entire Bay.

4.1.2 Temporal structure

The ideal data set would contain measurements from samples made at random times of day and dates, at selected times and dates fixed in a consistent defensible pattern, or at times chosen to illustrate a specific process. Several of the data sets have a defensible time pattern to the samples.

The TPWD data set has samples taken with consistent temporal regularity to detect change over seasons, providing assurance that segments of the Bay will be sampled within a season. However, the diurnal frequency of sampling is not randomly or regularly distributed. Some of the gear is fished at consistent times of the day, e.g. gill nets are fished over night and shrimp trawls are fished during the day. Each gear covers a limited time of the diurnal cycle. However, the times of day in which trawls, bag seines and oyster dredges are deployed vary from sampling site to sampling site and may have an

impact on the species and number captured. Analysis of this data is based on the assumption that all collections are equivalent in their representation of species diversity and abundance in the sampling area.

The survey of colonial water birds has a specified temporal pattern that is occasionally modified. Volunteers conducting the survey try to visit the colony sites during a two-week period at the end of May and the beginning of June each year. Sometimes weather may delay the census or may prevent counting of some colony sites. This data set has a consistent temporal pattern based on dates, but it is not consistent in the context of seasonal change and environmental triggers of breeding behavior in birds. It is the best data set available on water birds associated with Galveston Bay. We make the assumption that the annual surveys are equivalent samples of breeding bird abundance.

The water and sediment quality data obtained from TCEQ has the most irregular temporal pattern of any data set. No sampling sites have randomly or evenly distributed samples over time. There are significant temporal gaps in data collection from large areas of the Bay and its tributaries. The graphs of many parameters shown below have missing data points for years in which no samples were collected. There are cases in which years with few data points are followed by years in which samples were collected in every month. Most of the water quality parameters show temporal clumping of samples across years, which makes detection of long term temporal patterns much more difficult. The sample sizes used to calculate annual averages will be shown on the trend graphs below to permit the reader to judge the validity of the temporal pattern.